niques have failed. These endovascular methods usually employ a transfemoral approach using local anesthesia and mild sedation. Intravascular catheters are guided into the intracranial circulation under direct fluoroscopic control. Detachable balloons may be placed in aneurysms or proximal vessels; various particles, thrombogenic coils, or glue may be injected into vascular malformations; or cerebral arteries narrowed by vasospasm may be dilated with microballoons. At present, these relatively new techniques have potential advantages but some limitations.

For difficult intracranial aneurysms, or for patients in poor medical or neurologic conditions, endovascular balloon occlusion of an aneurysm or feeding artery offers several benefits: an open craniotomy with general anesthesia and brain retraction is avoided; the patient's neurologic condition can be continually monitored during the procedure, and if the test occlusion is not tolerated, the balloon can be deflated; and an immediate, high-quality angiogram can be done following the balloon placement to verify the completeness of the occlusion and the patency of normal vessels. Serious pitfalls include immediate or delayed aneurysmal rupture due to subtotal occlusion and incomplete aneurysmal thrombosis; balloon rupture or balloon migration leading to hemorrhage or ischemic complications, especially in giant aneurysms wherein more than one balloon is required; persistent mass effect of the inflated balloons, even after aneurysmal thrombosis; and occlusion of the origins of perforators that are not angiographically visualized. Long-term follow-up in patients undergoing these procedures is still being conducted. Further research to find a safer endovascular therapy for difficult aneurysms is clearly warranted, and we are currently investigating the use of retrievable thrombogenic coils.

Endovascular embolization of intracranial vascular malformations is proving to be extremely valuable, usually as an adjunct to conventional microsurgical or radiosurgical procedures. Advantages include awake monitoring of patients with test injections of amobarbital sodium before definitive embolization; the ability to obliterate deep feeders or components of arteriovenous malformations (AVMs) that are surgically difficult; and the ability to stage the obliteration of large malformations, potentially allowing for the gradual return to normal of markedly altered hemodynamics. For large AVMs, we have recently been using embolization to reduce the nidus size before a radiosurgical procedure in an attempt to increase the obliteration rate and decrease the incidence of complications. In 45 patients receiving this combined therapy, the results are encouraging, although long-term follow-up is still needed. In select cases, such as carotid-cavernous fistulas, dural AVMs, vein of Galen aneurysms, and occasional parenchymal AVMs, endovascular treatment results in complete angiographic obliteration of the lesion. Limitations include the risk of inducing hemorrhage or infarction, either immediate or delayed; the small incidence of venous sinus thrombosis if a transvenous approach is used; and the possibility of AVM recanalization if the malformation is not removed. It is rare to obliterate completely a parenchymal AVM with endovascular treatment alone.

Balloon angioplasty for symptomatic vasospasm following subarachnoid hemorrhage is being attempted in specialized neurosurgical centers. Because delayed ischemic deterioration from vasospasm is still a major problem despite the use of hypervolemic, hypertensive therapy and systemic calcium antagonists, balloon angioplasty could have substantial therapeutic potential. Problems associated with the method include aneurysmal rupture if its neck has not been secured; a failure to improve the neurologic condition if unrecognized infarction has already occurred; the risk of inducing hemorrhage in an infarcted territory; and difficulty gaining access to the narrowest (often most symptomatic) arteries, smaller arterial branches, and perforators. The long-term side effects of intracranial angioplasty are also not known.

Endovascular therapy for cerebrovascular disorders has already made a major positive contribution. At present it still has certain limitations and does not replace open microsurgical techniques for patients in good condition with accessible lesions. With further technical advances and improvements in patient selection criteria, its role will undoubtedly be expanded and become better defined.

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Implanting Fetal Tissue to Treat Parkinson's Disease

THE CONCEPT OF RESTORING NEUROLOGIC function by transplanting neural tissue is old. A clear demonstration of its feasibility, however, came in 1979 with the publication of two important studies. In both, the researchers partially reversed the behavioral abnormalities seen in rats with pharmacologically induced nigrostriatal lesions by transplanting fetal tissue into the brain. The clinical implications for Parkinson's disease are clear. The motor disturbances seen in patients with Parkinson's disease primarily result from the loss of dopaminergic neurons in the pars compacta of the substantia nigra. These neurons project to the striatum where the release of dopamine from synaptic vesicles modulates motor function. The systemic delivery of levodopa dramatically improves function in these patients, but the results are far from ideal. The local production of dopamine in the striatum by transplanted tissue holds the promise of even greater clinical improvement.

In the initial attempts at transplantation in humans, autologous adrenal tissue was used as the source for dopamine. At best, the results have been limited and transient. The mechanism underlying the observed improvements is not known, but autopsy studies and research in animals strongly suggest that the release of catecholamines by viable graft cells is not a factor. The bulk of the data obtained from studies of animals over the past ten years indicates that fetal brain tissue is superior to adrenal tissue for this purpose. In 1987 a Scandinavian team did the first implantation of fetal mesencephalic cells into the human striatum. Perhaps as many as 100 similar procedures have been performed throughout the world to date, although documentation in the English-language literature has been scarce. Eight fetal cell implantations have been done in this country. The first of these has been described in detail: that

one patient has shown considerable improvement in motor function, sustained at one year. The degree of improvement mirrors that seen with the third patient in the Scandinavian series, as reported recently in *Science*. Positron emission tomographic scans using G-L-[^{18}F]fluorodopa in these patients suggest that viable graft cells are producing dopamine within the striatum.

Neural transplantation is in its infancy. The optimal age at which the embryonic tissue should be harvested is reasonably clear, but the method of delivery, the number of cells implanted, the exact target within the striatum, unilateral versus bilateral transplants, the immunologic factors at play, and the use of growth factors are but some of the issues that still need to be more thoroughly addressed. We are clearly on the verge of a new era in which the restoration of function within the central nervous system will be commonplace.

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Endoscopic Neurosurgery

IMAGE-DIRECTED STEREOTACTIC METHODS have enabled the safe and precise placement of endoscopes into the brain. The miniaturization of endoscopic instruments has enabled the development of smaller-diameter endoscopes, which minimizes the disruption of normal brain in approaching deep lesions. Miniaturization and technical improvements have occurred in optics (rigid as well as fiberoptic systems), operating instruments (rigid and flexible microforceps), continuous suction and irrigation systems, and fiber systems for delivering laser energy. In addition, intraoperative ultrasonography through a burr hole allows real-time monitoring of intracranial contents.

Endoscopic systems have now been used in numerous situations with relatively low complication rates, including the aspiration of colloid cysts of the third ventricle, biopsy and resection of cystic and intraventricular tumors, the evacuation of intracerebral hematomas, and a terminal-third ventriculostomy through a foramen of Monroe for hydrocephalus in patients with aqueductal stenosis or pineal region tumors.

A recent series reported on 109 endoscopic procedures for the evacuation of hematomas and 24 for biopsy and subtotal resection of a variety of intracranial tumors. Surgical morbidity was approximately 4% in the patients with intracranial hemorrhage and negligible in the patients with tumors.

Whether the endoscopic treatment of such lesions can be more effective than conventional management remains to be demonstrated, but certainly such procedures can be carried out with a high degree of safety due to the precision of localizing techniques and minimal invasiveness of the endoscopic instruments.

With advances in endoscopic technology, surgical instrumentation, and energy delivery (laser), endoscopic neurosurgical techniques may become increasingly important in the management of a variety of intracranial disorders.

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Indications for Stabilization in the Management of Lumbar Disc Disease

THE DIAGNOSIS OF MECHANICAL INSTABILITY of the lumbar spine is difficult to make with certainty and frequently is a diagnosis of exclusion. Practitioners caring for patients with degenerative lumbar disc disease must never forget the anatomy of the back, the important stabilizing role of the ligaments, facet joints, facet capsules, and musculature, and the important anatomic relationship of the disc to the intervertebral foramina. Any patient who has had a previous back operation, especially for the removal of a degenerative disc, may have instability at the operative level. This is especially true at the L4-5 level, which is the most mobile of the lumbar spine. A number of patients in whom the "failed back syndrome" develops after disc excision are suffering from excessive mobility at a motion segment(s) and will benefit from a stabilization procedure; the trick is to identify those patients in whom further surgical intervention is likely to be beneficial.

Most patients who have mechanical instability of the spine will have both back and leg pain, but the back pain is predominant. On physical examination, they will have impressive muscle spasm of the paravertebral musculature and be unwilling to move the back except with flexion at the hips. Plain lumbar spine films in flexion and extension may show excessive movement of the injured motion segment(s), there may be evidence of pseudospondylolisthesis, and unexpected iatrogenic pars and facet fractures are not infrequently identified. Magnetic resonance imaging or myelography usually is not impressively abnormal; there may be residual scarring or mild disc bulging, but in most of these patients large structural lesions are absent. The best preoperative predictor of whether a particular patient will benefit from a fusion is the response to a trial of immobilization in an acrylic body jacket. This jacket cannot be removed and is left on for four to six weeks. Patients who will benefit from fusion are able to reduce substantially their requirement for medication, often become pain-free in the jacket, and will have fairly prompt recurrence of significant back pain when the jacket is removed and replaced with a rigid but removable brace.

A fusion operation can be accomplished by a number of techniques with and without instrumentation and with both anterior and posterior approaches. The basic key to obtaining a solid fusion is bone bridging across the area of motion. Instrumented fusions without adequate bone or proper attention to preparing the fusion bed will ultimately fail because the initial stability provided by the instrumentation is lost as the metal parts loosen with continued motion over time.

Because spinal fusion for patients with the failed-back syndrome carries no guarantee that symptoms will be ameliorated, patients should be considered as candidates for